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(54) Title: CORROSION PROTECTION ON METALS

(57) Abstract: Corrosion protection on metals The present invention relates to a coating on a metal to protect against corrosion, comprising the following layer sequence: (i) metal surface, (ii) layer based on a sol containing silicon compounds, (iii) layer based on at least one organosilane, (iv) if desired, one or more coating films. The present invention further relates to a process for producing such a coating and to the use thereof.

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Corrosion protection on metals

The present invention relates to a special coating on a metal to protect against corrosion, to a process for producing such a coating, and to the use thereof.

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Anti-corrosion compositions for metals and also adhesion promoters (referred to hereinbelow as primers) based on organosilanes or SiO_2 sol have been known for a long time and have been described in diverse form. Unfortunately the known systems still leave something to be desired.

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Common methods of producing anti-corrosion layers on metallic surfaces include chromating, phosphating, coating, and anodizing.

The industrial significance of chromating is at the present time continuing to decline owing to toxicological problems and corresponding reclassification of the chromates (EU Directive 2000/53/EG). Despite the good corrosion protection properties of chromating, therefore, the development of new, chromium-free systems is of generally high interest.

20 Methods of phosphating iron, steel, zinc, and aluminum have long been state of the art. Phosphating in combination with a coating is enough to afford an entirely acceptable corrosion control, whereas the two systems alone do not lead to the desired results.

25 Electrolytically produced protective oxide films on metals, such as aluminum or titanium, despite affording adequate protection against corrosion, exhibit brittleness as the thickness of the oxide films increases, and require a large amount of energy for their production.

30 Present developments are attempting to deposit perfect monolayer films on the metal surfaces, or are working with conversion coats of cerium [Galvanotechnik 92 (12), 2001, 3243].

Further approaches to avoiding chromates(VI) are formulations which contain chromium(III) and which therefore cannot be considered to be free of heavy metals.

- 5 Eco-friendly anti-corrosion layers can be obtained with silanes and also hydrolyzed silanes (WO 98/19798, WO 00/46310) or with silane-based sol-gel condensates (US 5 200 275).

10 For the coating of the surfaces the metal substrates are generally first degreased and cleaned. The cleaning steps may include treatment with organic solvents and also alkaline and acidic pickling operations [Metalloberfläche, 29 (10), 1975, 517]. The silanes are hydrolyzed in aqueous or at least water-containing solutions and then contacted with the metal surface by immersion, spraying and/or spin coating applications. Curing or condensation takes place in air at room temperature or
15 elevated temperature.

WO 98/30735 discloses the twofold coating of the metal with organosilane solutions. The film thicknesses achieved in that case are normally between 10 and 100 nm.

20 Sol-gel systems (also referred to hereinbelow as sol) are prepared by means of an acidic or basic catalyst from hydrolyzable silicon compounds, often in combination with corresponding Al, Ti and/or Zr precursors. For this purpose the components are hydrolyzed together and converted into a sol or a gel. The solvent/diluent used
25 can be an alcohol which is also formed during the hydrolysis of the compounds. The coating composition can be applied to the metallic substrates in turn by means of a coating method already mentioned above. The coating composition is applied preferably in dry film thicknesses of from 1 to 50 µm without any final coating with a topcoat material being envisaged (DE-A 198 13 709).

30 EP 1 130 066 A1 discloses corrosion-protected metal surfaces which have been pretreated with a silane composition and subsequently extrusion coated with a polyamide compound. The water- and alcohol-containing silane composition

employed is based, inter alia, on hydrolyzates, condensates and/or cocondensates, starting from alkoxysilanes Q which carry functional groups, such as aminoalkylalkoxysilanes, and alkoxysilanes M, such as alkylalkoxysilanes, alkenylalkoxysilanes and tetraalkoxysilanes, the sum of components M and Q
5 being present in a molar ratio of $0 \leq M/Q < 20$.

It is an object of the present invention to provide a further means of protecting a metal against corrosion. A particular concern was to protect specifically the surface of copper, aluminum and aluminum alloys against corrosion by means of a
10 coating. A further concern was to find a highly effective and nevertheless eco-friendly solution.

This object is achieved in accordance with the invention as per the details in the patent claims.
15

Surprisingly it has been found that a particularly effective anti-corrosion coating is obtainable on a metal surface in a comparatively simple, economical, and eco-friendly way by

- optionally pretreating the metal surface,
- 20 - applying a sol containing silicon compounds to the metal surface,
- if desired, partly or fully drying the applied sol film,
- coating the sol film with an in particular monomeric or else a partly hydrolyzed or oligomeric organosilane,
- drying and also curing the sol and organosilane films, and
- 25 - if desired, applying one or more coating films to the layer system thus obtained, i.e., coating it, drying the coats, and also curing them.

The present invention accordingly provides a coating on a metal to protect against corrosion, comprising the following layer sequence:

- 30 (i) metal surface,
- (ii) layer based on a sol containing silicon compounds,
- (iii) layer based on at least one monomeric organosilane,
- (iv) if desired, one or more coating films.

A coating of this kind, obtainable by applying the teaching of the invention, to protect metals against corrosion generally constitutes a very thin, hydrophobic, transparent coating with barrier effect. It is in particular an especially effective barrier film for electrolyte solutions and so advantageously brings about passive protection against corrosion for metals, particularly for copper, aluminum and aluminum alloys.

The present coating can be employed effectively either with or without coating film sequence (iv).

10

Accordingly the sol-organosilane coating (ii)/(iii) of the invention can be employed additionally as an oil- and dirt-repellent coating system, in which case the layer (iii) is based preferably on the use of fluoralkylalkoxysilanes of the general formula $R^1-Y_u-(CH_2)_2Si(R^2)_y(OR)_{3-y}$. In this formula R^1 is preferably a mono-, oligo- or perfluorinated alkyl group having from 1 to 13 carbon atoms, i.e. a linear,

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group having 1 to 8 carbon atoms or is an aryl group, and y is 0 or 1. In this case it is possible, for example, to use tridecafluoro-1,1,2,2-tetrahydrooctyltrimethoxysilane or tridecafluoro-1,1,2,2-tetrahydrooctyltriethoxysilane, to name but a few examples.

20

For a layer (iii) it is also possible to choose at least one functional group of the organosilane so that it attaches chemically to a coating material applied to it. Thus preference is given to aminosilanes or expoxy-functional silanes, such as 3-aminopropyltrialkoxysilane or 3-glycidyloxypropyltrialkoxysilane, for acrylic, urethane or epoxy coating materials, and organosilanes containing double bonds, such as 3-methacryloxyoxylpropyltrialkoxysilane or vinyltrialkoxysilanes, for free-radically curing coating systems, alkoxy here and below preferably being methoxy, ethoxy, propoxy, butoxy or 2-methoxyethoxy.

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30

With coatings according to the invention, it is observed in a corrosion test, particularly in the case of aluminum, that there is virtually no "scribe creep" or

corrosive migration beneath the coating material starting from the scribe mark. Accordingly, through the formation of very thin barrier films, the coatings of the invention afford good passive protection against corrosion. This inventively thin anti-corrosion coating also effects astonishingly good coverage of rough surfaces, such as mechanically abraded aluminum sheets, for example. Consequently coatings of this kind may replace not only chromating but also the cathodic electrocoating which normally follows.

The advantages of the present coatings are as follows:

- 10 - outstanding protection against corrosion on metal surfaces even at film thicknesses below 1 μm and even without a further coating system;
- extremely high electrical volume resistances;
- comparatively eco-friendly composition;
- the possibility of avoiding chromating;
- 15 - simple and economic application of the composition;
- effective coating, both mechanically and chemically, and also, in particular under the influence of humidity in conjunction with salt;
- particularly good adhesion to the metal to be protected and to any subsequent coatings, such as paint or polymer coatings.

20

The present invention also provides the process for producing a coating of the invention, which comprises

- if desired, pretreating the metal surface,
- applying a sol containing silicon compounds to the metal surface,
- 25 - If desired, drying the applied sol film,
- coating the sol film with an organosilane,
- drying and also curing the sol and organosilane films, and
- if desired, applying one or more coating films to the layer system thus obtained.

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The process of the invention is preferably employed on the surface of a metal (i) from the group consisting of aluminum, aluminum alloy, magnesium, magnesium alloy, zinc, zinc alloy, titanium, titanium alloy, iron, iron alloy, galvanized iron

sheet, galvanized iron alloy, tin, tin alloy, copper, copper alloy, and silver and silver alloy.

When employing the process of the invention it is generally not absolutely
5 necessary to treat the metal surface. However, it is advisable to clean the metal surface to be coated beforehand. For example, the metal surface to be coated can be degreased using an appropriate solvent. Alternatively, the metal surface may be pretreated mechanically by abrading, thermally by heating, or chemically by etching. The metal surface to be treated should at least, however, be dry.

10

In the process of the invention a sol containing silicon compounds can be applied to the optionally pretreated metal surface by means, for example, of dipping, brushing, spraying, knife coating or spin coating.

15 A sol of this kind containing silicon compounds can be prepared in a conventional manner. In the process of the invention it is preferred to employ at least one alkoxysilane from the group consisting of tetramethoxysilane, methyltrimethoxysilane, propyltrimethoxysilane, isopropyltrimethoxysilane, octyltrimethoxysilane, hexadecyltrimethoxysilane, octadecyltrimethoxysilane,
20 tetraethoxysilane, methyltriethoxysilane, propyltriethoxysilane, isopropyltriethoxysilane, octyltriethoxysilane, hexadecyltriethoxysilane and octadecyltriethoxysilane or a mixture of at least two of the aforementioned alkoxysilanes. Generally for this purpose an alkoxysilane is subjected to controlled hydrolysis and the hydrolysate is reacted to the sol with heating and thorough
25 mixing where appropriate. To this end, the ripening sol is appropriately reacted at a temperature in the range from 10 to 80°C, preferably from 10 to 60°C, more preferably from 20 to 30°C, for from 1 minute to 24 hours, in particular for from 10 to 60 minutes. Said reaction may where appropriate be conducted in the presence of a hydrolysis catalyst, such as an organic or a mineral acid, for example, such
30 as acetic acid, citric acid or phosphoric acid, sulphuric acid or nitric acid or a base, such as sodium methoxide, sodium ethoxide, sodium hydroxide, potassium hydroxide, ammonia or organic amines, such as alkylamines, for example. The hydrolysis catalyst can be introduced in a mixture with the water, which here is

used for hydrolysis. Furthermore, a diluent/solvent can be added to the actual hydrolysate or to the sol obtained, an example of such a diluent/solvent being the alcohol corresponding to the alkoxy group of the alkoxy silane employed. The sol used in accordance with the invention preferably includes water, methanol, ethanol, isopropanol, butanol, methoxypropanol, butyl glycol or a mixture of at least two of the aforementioned solvents/diluents. Thus the sol may contain from 1 to 99% by weight, preferably from 15 to 80% by weight, more preferably from 30 to 50% by weight, of solvent/diluent, the amount being based on the overall makeup of the present sol. The sol can also be adjusted to a pH of from 1 to 6 by addition of one of the abovementioned acids.

By way of example a sol may be obtained from 50 to 100 parts by weight of at least one alkoxy silane, methyltrialkoxysilane and/or tetraalkoxysilane, for example, 0.01 to 5 parts by weight of acid, phosphoric acid for example, 5 to 150 parts by weight of water, and optionally 10 to 200 parts by weight of alcohol, ethanol for example, hydrolysis and subsequent reaction being carried out suitably with stirring at a temperature of from 10 to 80°C for a time of from 10 minutes to 5 days. A formulation obtained in this way, which is generally clear, or opalescent to milky, can then be used as it is or in diluted form in the process of the invention.

In the process of the invention, after the sol has been applied to the metal surface, the sol film applied to the metal surface can be subjected to partial thermal drying or to drying or curing in an intermediate step. Drying takes place preferably at a temperature of up to 220°C, in particular from 10 to 200°C, generally producing a sol layer (ii) which is dry to hard on the surface, is predominantly clear, and adheres well to the metal.

The dry film thickness of the layer (ii) is suitably from 0.1 μm to 10 μm , preferably from 0.3 μm to 5 μm and very preferably from 0.5 μm to 2 μm .

Thereafter, in the process of the invention, the organosilane can be applied by dipping, spraying or brushing to the sol layer produced beforehand and can be

subjected to partial thermal drying, drying and/or curing to give the layer (iii).

For producing the layer (iii) preference is given to aqueous or aqueous-alcoholic solutions of said organosilanes. The organosilanes may be in monomeric form,
5 partially hydrolyzed form, or else, possibly, partly oligomerized form.

The layer (iii) preferably has a dry film thickness of from 5 to 500 nm, in particular from 10 to 100 nm.

10 An alternative possibility in accordance with the invention is to apply a sol to an optionally pretreated metal surface and to cover this sol film with the organosilane, subsequently subjecting the sol and organosilane films thus produced to joint full or partial drying or curing. A procedure of this kind allows a saving to be made of one drying or curing step.

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In the process of the invention for producing the layer (iii) it is therefore preferred to use the following organosilanes:

aminoalkyl-functional alkoxysilanes from the group consisting of 3-amino-propyltrimethoxysilane, 3-aminopropyltriethoxysilane, N-(2-aminoethyl)-3-aminopropyltrimethoxysilane, N-(2-aminoethyl)-3-aminopropyltriethoxysilane, N-(2-aminoethyl)-3-aminopropyl-methyldimethoxysilane, N-(2-aminoethyl)-3-aminopropyl-methyldiethoxysilane, N,N-di(2-aminoethyl)-3-aminopropyltri-methoxysilane, N,N-di(2-aminoethyl)-3-aminopropyltriethoxysilane, N-[N'-(2-aminoethyl)-2-aminoethyl]-3-aminopropyltrimethoxysilane, N-[N'-(2-aminoethyl)-2-aminoethyl]-3-aminopropyltriethoxysilane, N-methyl-3-aminopropyltrimethoxy-silane, N-methyl-3-aminopropyltriethoxysilane, N-(n-butyl)-3-aminopropyl-trimethoxysilane, N-(n-butyl)-3-aminopropyltriethoxysilane, N-cyclohexyl-3-aminopropyltrimethoxysilane, N-cyclohexyl-3-aminopropyltriethoxysilane, N-phenyl-3-aminopropyltrimethoxysilane, 3-aminopropyl-methyldimethoxysilane, 3-aminopropylmethyldiethoxysilane, bis(3-trimethoxysilylpropyl)amine, and bis(3-triethoxysilylpropyl)amine or
25 epoxy-functional alkoxysilanes from the group consisting of 3-glycidyloxypropyltrimethoxysilanes, 3-glycidyloxypropyltriethoxysilanes, β -(3,4-

30

epoxycyclohexyl)ethyltrimethoxysilane or organosilanes containing double bonds, from the group consisting of vinyltrimethoxysilane, vinyltriethoxysilane, vinyltris(2-methoxyethoxy)silane, 3-methacryloyloxypropyltrimethoxysilane or

- 5 fluoro-functional organosilanes of the general formula $R^1-Y_u-(CH_2)_2Si(R^2)_y(OR)_{3-y}$, where R^1 is a mono-, oligo- or perfluorinated alkyl group having from 1 to 13 carbon atoms or a mono-, oligo- or perfluorinated aryl group, Y is a $-CH_2-$, $-O-$ or $-S-$ group with u being 0 or 1, R^2 is a linear, branched or cyclic alkyl group having 1 to 8 carbon atoms or is an aryl group, and y is 0 or 1, or
- 10 a mixture of at least two of the aforementioned organosilanes or a partial hydrolysate of the aforementioned organosilanes or an aqueous-alcoholic solution of the aforementioned organosilanes, i.e., a partial or complete hydrolysate of the aforementioned organosilanes, or condensation products of the aforementioned organosilanes and hydrolysates, or an aqueous-
- 15 alcoholic solution of the aforementioned organosilanes, hydrolysates or condensation products. Such a solution contains preferably from 0.01 to 99.99% of the aforementioned organosilanes, hydrolysates or condensation products and from 0.01 to 99.99% by weight of water or alcohol, or any desired mixture of water and alcohol, based in each case on 100% by weight of solution.

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To a generally already cured layer sequence (ii)/(iii) of this kind it is additionally possible to apply one or more coating films in a conventional manner, preference being given to coating films having a thickness of from 1 to 500 μm , in particular from 5 to 100 μm , very preferably from 10 to 50 μm .

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Such coating materials may, for example, be matt or high-gloss clearcoats, decorative coats, color coats, and pigmented coating materials, and also scratch-resistant or abrasion-resistant topcoats.

- 30 In the process of the invention it is preferred to produce at least one coating layer (iv) from the group consisting of acrylic, epoxy, urethane, polyester, and synthetic resin coating materials.

The present invention likewise provides for the use of a coating of the invention to protect against corrosion for a metal from the group consisting of aluminum, aluminum alloys, magnesium, magnesium alloys, zinc, zinc alloys, titanium, titanium alloys, iron, iron alloys, galvanized iron sheet, galvanized iron ally, tin, tin alloys, copper, copper alloys, and silver and silver alloys.

The coating of the invention can be used to particular advantage in automobile construction, in mechanical engineering, in shipbuilding, in aircraft construction, or for house construction components.

The invention accordingly provides a process which allows a new coating to be produced on metal surfaces for the purpose of protecting the metals against corrosion, in a way which is advantageous in that it is comparatively simple and economical. Through the coating of the invention, in particular, a distinct improvement is achieved in the protection of copper, aluminum and aluminum alloys against corrosion, the anti-corrosion coating produced in accordance with the invention further possessing excellent adhesion directly on the metallic substrate and also being obtainable in an advantageous way.

The present invention is illustrated by the following examples, without restriction of its subject matter.

Examples

Example 1

1.1 Preparation of the sol:

120 g of tetraethoxysilane (DYNASIL® A) und 300 g of methyltriethoxysilane (DYNASYLAN® MTAS) were charged to a 4-necked flask with mechanical stirrer, reflux condenser, dropping funnel, and thermometer. With intensive stirring 42 g of deionized water were added dropwise over the course of 5 minutes and the mixture was diluted with 138 g of isopropanol. The pH was adjusted to 3.5 using

phosphoric acid. The mixture, which was cloudy to start with, was stirred for a further 5 hours. This gave a clear sol.

For application, 100 parts by weight of sol were diluted with 95 parts by weight of isopropanol and the diluted sol was activated by adding 5 parts by weight of water and then stirring it for 30 minutes.

1.2 Cleaning of the metals:

All the metal sheets were degreased with organic solvents, pickled in dilute (10%) alkaline cleaning solution (CARELA[®] SP, R. Späne GmbH) at 70°C for 10 to 20 seconds, and then rinsed off with deionized water. The sheets were further pickled in dilute (0.0016 mol/l) nitric acid for 5 minutes, rinsed with deionized water, and dried.

1.3 Application of the coatings:

Untreated test sheets (of Al Alloy 6016: $\text{AlMg}_{0.4}\text{Si}_{1.2}$) were cleaned in accordance with 1.2 and immersed for 5 minutes in the activated coating sol A described under 1.1. The sheets were stood up vertically in order to allow excess sol to drip off. After a drying time of 2 h at room temperature the sheets were coated a second time with a 1% strength alcoholic-aqueous solution of triethoxy(3,3,4,4,5,5,6,6,7,7,8,9-tridecafluorooctyl)silane. The sheets were then dried at 200°C for 10 minutes.

1.3 Testing of the sheets:

The sheets exhibited a high static contact angle with respect to water, of 103°. The sheets were subsequently stored for 10 days in the acidic corrosion solution (solution as per CASS-Test, DIN.50021) in closed corrosion chambers at 50°C. The corrosion solution was replaced daily. There was only a slight attack on the surface of the coated sheets.

Example 2

2.1 Application of the coating:

- 5 Bright copper sheets and copper sheets with oxide surfaces were cleaned in accordance with 1.2, but without the HNO_3 pickling, or were only degreased with organic solvents. The copper sheets were immersed in the activated coating sol described under 1.1 for 5 minutes. The sheets were then stood up vertically in order to allow excess sol to drip off. Following initial drying at room temperature
- 10 the sheets were coated a second time for 5 minutes with a 1% strength alcoholic-aqueous solution of N-(n-butyl)-3-aminopropyltrimethoxysilane, which contained acetic acid. After brief initial drying at room temperature, curing was carried out for 10 minutes at 150°C (bright copper) or for 10 minutes at from 100 to 190°C (oxide surfaces). The silane-coated metal sheets were coated with a 2-component
- 15 polyurethane varnish (Standex GmbH) and dried at 60°C for 600 minutes. The thickness of the varnish layer is approximately 25 μm .

2.2 Testing of the sheets:

- 20 The coated copper sheets were stored in deionized water, after which the copper ion content of the aqueous phase was determined. For comparison, uncoated sheets were also subjected to this elution test. After 48 hours the solutions with the uncoated sheets were found by means of ICP (inductively coupled plasma) mass spectrometry to have an increased copper concentration, while in the case
- 25 of the sheets with an applied barrier layer it was not possible to detect any copper ions dissolved out of the metal.

Example 3

30 3.1 Application of the coatings:

Test sheets (of Al Alloy 6016) were cleaned in accordance with 1.2 and immersed

for 5 minutes in the activated coating sol described under 1.1. The sheets were stood up vertically in order to allow excess sol to drip off. After initial drying at room temperature the sheets were coated a second time for 5 minutes with a 1% strength alcoholic-aqueous solution of N-(n-butyl)-3-aminopropyltrimethoxysilane, which contained acidic acid. After brief initial drying at room temperature, curing was carried out at 200°C for 10 minutes. The silane-coated aluminum sheets were coated with a 2-component polyurethane varnish (Standex GmbH) and dried at 60°C for 60 minutes. The thickness of the varnish film is approximately 25 µm.

10 3.2 Testing of the sheets:

In the case of the test sheets coated in 3.1 there was no scribe creep even after 1000 h in the salt spray mist test (DIN 50021). The abrasion resistance (to DIN EN 24624) of the coating was very high, at levels of > 27 MPa.

What is claimed is:

1. A coating on a metal to protect against corrosion, comprising the following layer sequence:
 - (i) metal surface,
 - (ii) layer based on a sol containing silicon compounds,
 - (iii) layer based on at least one organosilane,
 - (iv) if desired, one or more coating films.
2. The coating as claimed in claim 1, comprising a metal (i) selected from the group consisting of aluminum, aluminum alloy, magnesium, magnesium alloy, zinc, zinc alloy, titanium, titanium alloy, iron, iron alloy, galvanized iron sheet, galvanized iron alloy, tin, tin alloy, copper, copper alloy, and silver and silver alloy.
3. The coating as claimed in claim 1 or 2, wherein the sol used to produce the sol layer (ii) is based on at least one tetraalkoxysilane and/or at least one alkylalkoxysilane.
4. The coating as claimed in any of claims 1 to 3, wherein the sol used to produce the sol layer (ii) is based on at least one alkoxysilane from the group consisting of tetramethoxysilane, methyltrimethoxysilane, propyltrimethoxysilane, isopropyltrimethoxysilane, octyltrimethoxysilane, hexadecyltrimethoxysilane, octadecyltrimethoxysilane, tetraethoxysilane, methyltriethoxysilane, propyltriethoxysilane, isopropyltriethoxysilane, octyltriethoxysilane, hexadecyltriethoxysilane, and octadecyltriethoxysilane or a mixture of at least two of the aforementioned alkoxysilanes.
5. The coating as claimed in any of claims 1 to 4, wherein the organosilane used to produce the layer (iii) is at least one aminoalkyl-functional alkoxysilane from the group consisting of 3-aminopropyltrimethoxysilane, 3-aminopropyltriethoxysilane, N-(2-aminoethyl)-3-aminopropyltrimethoxysilane, N-(2-aminoethyl)-3-

- aminopropyltriethoxysilane, N-(2-aminoethyl)-3-aminopropyl-
 methyldimethoxysilane, N-(2-aminoethyl)-3-aminopropyl-
 methyldiethoxysilane, N,N-di(2-aminoethyl)-3-aminopropyltrimethoxysilane,
 N,N-di(2-aminoethyl)-3-aminopropyltriethoxysilane, N-[N'-(2-aminoethyl)-2-
 5 aminoethyl]-3-aminopropyltrimethoxysilane, N-[N'-(2-aminoethyl)-2-
 aminoethyl]-3-aminopropyltriethoxysilane, N-methyl-3-aminopropyltri-
 methoxysilane, N-methyl-3-aminopropyltriethoxysilane, N-(n-butyl)-3-
 aminopropyltrimethoxysilane, N-(n-butyl)-3-aminopropyltriethoxysilane, N-
 cyclohexyl-3-aminopropyltrimethoxysilane, N-cyclohexyl-3-
 10 aminopropyltriethoxysilane, N-phenyl-3-aminopropyltrimethoxysilane, 3-
 aminopropylmethyldimethoxysilane, 3-aminopropylmethyldiethoxysilane,
 bis(3-trimethoxysilylpropyl)amine, and bis(3-triethoxysilylpropyl)amine or
 at least one epoxy-functional alkoxysilane selected from the group
 consisting of 3-glycidyloxypropyltrimethoxysilanes, 3-
 15 glycidyloxypropyltriethoxysilanes, β -(3,4-
 epoxycyclohexyl)ethyltrimethoxysilane or
 at least one organosilane containing double bonds, selected from the group
 consisting of vinyltrimethoxysilane, vinyltriethoxysilane, vinyltris(2-
 methoxyethoxy)silane, 3-methacryloyloxypropyltrimethoxysilane or
 20 at least one fluoro-functional organosilane of the general formula $R^1-Y_u-(CH_2)_2Si(R^2)_y(OR)_{3-y}$, where R^1 is a mono-, oligo- or perfluorinated alkyl
 group having from 1 to 13 carbon atoms or a mono-, oligo- or perfluorinated
 aryl group, Y is a $-CH_2-$, $-O-$ or $-S-$ group with u being 0 or 1, R^2 is a linear,
 branched or cyclic alkyl group having 1 to 8 carbon atoms or is an aryl
 25 group, and y is 0 or 1, or
 a mixture of at least two of the aforementioned organoalkoxysilanes or
 a partial hydrolysate of the aforementioned organosilanes or
 an aqueous-alcoholic solution of at least one organosilane.
- 30 6. The coating as claimed in any of claims 1 to 5, comprising at least one
 coating film (iv) selected from the group consisting of acrylic, epoxy,
 urethane, polyester, and synthetic resin coating materials.

7. A process for producing a coating on a metal to protect against corrosion as claimed in any of claims 1 to 6, which comprises

- optionally pretreating the metal surface,
- applying a sol containing silicon compounds to the metal surface,
- 5 - if desired, drying the applied sol film,
- coating the sol film with an organosilane,
- drying and also curing the sol and organosilane films, and,
- if desired, applying one or more coating films to the layer system thus obtained.

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8. The process as claimed in claim 7, wherein the drying and/or curing of the films is conducted at a temperature in the range from 0 to 220 °C and for a period of more than 1 minute to 24 hours.

15 9. The use of the coating as claimed in any of claims 1 to 8 to protect against corrosion for a metal from the group consisting of aluminum, aluminum alloys, magnesium, magnesium alloys, zinc, zinc alloys, titanium, titanium alloys, iron, iron alloys, galvanized iron sheet, galvanized iron alloy, tin, tin alloys, copper, copper alloys, and silver and silver alloys.

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10. The use of the coating as claimed in any of claims 1 to 9 in automobile construction, in mechanical engineering, in shipbuilding, in aircraft construction or for house construction components.

INTERNATIONAL SEARCH REPORT

International Application No.

PCT/EP 03/10560

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 B05D7/00 C23C22/48 C23C22/52 C23C22/56 C09D4/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 B05D C23C C09D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 199 38 551 A (PENTH BERND) 22 February 2001 (2001-02-22) claims 1-7 column 1, line 3 - line 18	1, 2, 7
X	EP 0 492 306 B (ARMCO STEEL CO LP) 1 July 1992 (1992-07-01) claims 1-22 page 3, line 19 -page 4, line 14	1-10
A	WO 01 30922 A (INST NEUE MAT GEMEIN GMBH ;MENNIG MARTIN (DE); SCHMIDT HELMUT (DE)) 3 May 2001 (2001-05-03) claims 1-11 page 18, line 31 -page 19, line 27 --- -/-	1

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents:

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I document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

O document referring to an oral disclosure, use, exhibition or other means

P document published prior to the international filing date but later than the priority date claimed

T later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

X document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

Y document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

& document member of the same patent family

Date of the actual completion of the international search

18 December 2003

Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

International Application No.

PCT/EP 03/10560

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 98 30735 A (SUBRAMANIAN VIJAY ;ZHANG CHUMBIN (US); OOIJ WIM J VAN (US); UNIV C) 16 July 1998 (1998-07-16) claims 1-13 page 3, line 10 -page 5, line 33	1
A	US 6 403 164 B1 (JONSCHKE GERHARD ET AL) 11 June 2002 (2002-06-11) claim 1	1
A	US 5 759 629 A (VAN OOIJ WIM J ET AL) 2 June 1998 (1998-06-02) claim 1	1
A	EP 0 866 037 B (NISSAN MOTOR ;CENTRAL GLASS CO LTD (JP)) 23 September 1998 (1998-09-23) claims 1-14	1

INTERNATIONAL SEARCH REPORT

information on patent family members

International Application No

PCT/EP 03/10560

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
DE 19938551	A	22-02-2001	DE 19938551 A1	22-02-2001
EP 0492306	B	01-07-1992	US 5108793 A	28-04-1992
			BR 9105431 A	25-08-1992
			CA 2055153 A1	25-06-1992
			DE 69129527 D1	09-07-1998
			DE 69129527 T2	26-11-1998
			EP 0492306 A2	01-07-1992
			ES 2116273 T3	16-07-1998
			JP 3279611 B2	30-04-2002
			JP 4293789 A	19-10-1992
			MX 9102182 A1	01-06-1992
			US 5200275 A	06-04-1993
WO 0130922	A	03-05-2001	DE 19952040 A1	03-05-2001
			AU 1145301 A	08-05-2001
			BR 0015027 A	16-07-2002
			CA 2388856 A1	03-05-2001
			CN 1382073 T	27-11-2002
			WO 0130922 A2	03-05-2001
			EP 1230040 A2	14-08-2002
			JP 2003512921 T	08-04-2003
			TR 200201142 T2	21-08-2002
WO 9830735	A	16-07-1998	US 5750197 A	12-05-1998
			AU 726765 B2	23-11-2000
			AU 5862498 A	03-08-1998
			BR 9807057 A	02-05-2000
			EA 1588 B1	25-06-2001
			WO 9830735 A2	16-07-1998
			EP 1015662 A2	05-07-2000
			HU 0001015 A2	28-08-2000
			JP 2001507755 T	12-06-2001
			NZ 335877 A	26-01-2001
			PL 334657 A1	13-03-2000
			TR 9901568 T2	21-10-1999
			TW 445176 B	11-07-2001
			US 6261638 B1	17-07-2001
			ZA 9800133 A	08-01-1999
US 6403164	B1	11-06-2002	DE 19813709 A1	30-09-1999
			AT 213027 T	15-02-2002
			CA 2326050 A1	07-10-1999
			CN 1295629 T	16-05-2001
			DE 59900836 D1	21-03-2002
			DK 1068372 T3	21-05-2002
			WO 9950477 A1	07-10-1999
			EP 1068372 A1	17-01-2001
			ES 2171075 T3	16-08-2002
			JP 2002509990 T	02-04-2002
			NO 20004651 A	18-09-2000
			PT 1068372 T	31-07-2002
US 5759629	A	02-06-1998	AT 220576 T	15-08-2002
			AU 724454 B2	21-09-2000
			AU 5479198 A	29-05-1998
			BR 9712744 A	21-12-1999
			CA 2270879 A1	14-05-1998

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/EP 03/10560

Patent document cited in search report	Publication date	Patent family member(s)	Publication date	
US 5759629	A	CN 1239908 A , B	29-12-1999	
		DE 69714080 D1	22-08-2002	
		DE 69714080 T2	20-03-2003	
		DK 959990 T3	07-10-2002	
		WO 9819798 A2	14-05-1998	
		EP 0959990 A2	01-12-1999	
		ES 2180074 T3	01-02-2003	
		HU 0000458 A2	28-06-2000	
		JP 2001504146 T	27-03-2001	
		KR 2000053055 A	25-08-2000	
		NZ 335605 A	28-04-2000	
		PL 333326 A1	06-12-1999	
		TR 9901538 T2	21-09-1999	
		TW 422894 B	21-02-2001	
		ZA 9709948 A	05-11-1998	
EP 0866037	B	23-09-1998	JP 3397394 B2	14-04-2003
			JP 7138050 A	30-05-1995
			JP 7267684 A	17-10-1995
			EP 0866037 A2	23-09-1998
			DE 69422964 D1	16-03-2000
			DE 69422964 T2	15-06-2000
			DE 69430396 D1	16-05-2002
			DE 69430396 T2	21-11-2002
			EP 0658525 A2	21-06-1995
			US 5674625 A	07-10-1997
			US 5856016 A	05-01-1999